# Preliminary conclusions regarding the updated status of listed ESUs of West Coast salmon and steelhead

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## Co-manager review draft

**[This is a draft document being provided to state, tribal, and federal comanagers for technical review.]**

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## A. Chinook salmon

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**This section deals specifically with chinook salmon  It is part of a larger report, the remaining sections of which can be accessed from the same website used to access this section (http://www.nwfsc.noaa.gov/).  The main body of the report (Background and Introduction) contains background information and a description of the methods used in the risk analyses**.

# A. CHINOOK

## A.1 BACKGROUND AND HISTORY OF LISTINGS

Chinook salmon (*Oncorhynchus tshawytscha* Walbaum), also commonly referred to as king, spring, quinnat, Sacramento, California, or tyee salmon, is the largest of the Pacific salmon (Myers et al. 1998). The species historically ranged from the Ventura River in California to Point Hope, AK in North America, and in northeastern Asia from Hokkaido, Japan to the Anadyr River in Russia (Healey 1991). Additionally, chinook salmon have been reported in the Mackenzie River area of Northern Canada (McPhail and Lindsey 1970). Of the Pacific salmon, chinook salmon exhibit arguably the most diverse and complex life history strategies Healey (1986) described 16 age categories for chinook salmon, seven total ages with three possible freshwater ages. This level of complexity is roughly comparable to sockeye salmon (*O. nerka*), although sockeye salmon have a more extended freshwater residence period and utilize different freshwater habitats (Miller and Brannon 1982, Burgner 1991). Two generalized freshwater life-history types were initially described by Gilbert (1912): "stream-type" chinook salmon reside in freshwater for a year or more following emergence, whereas "ocean-type" chinook salmon migrate to the ocean predominately within their first year. Healey (1983, 1991) has promoted the use of broader definitions for "ocean-type" and "stream-type" to describe two distinct races of chinook salmon. This racial approach incorporates life history traits, geographic distribution, and genetic differentiation and provides a valuable frame of reference for comparisons of chinook salmon populations. For this reason, the BRT has adopted the broader "racial" definitions of ocean- and stream-type for this review.

Of the two life history types, ocean-type chinook salmon exhibit the most varied and plastic life history trajectories. Ocean-type chinook salmon juveniles emigrate to the ocean as fry, subyearling juveniles (during their first spring or fall), or as yearling juveniles (during their second spring), depending on environmental conditions. Ocean-type chinook salmon also undertake distinct, coastally oriented, ocean migrations. The timing of the return to freshwater and spawning is closely related to the ecological characteristics of a population's spawning habitat. Five different run times are expressed by different ocean-type chinook salmon populations: spring, summer, fall, late-fall, and winter. In general, early run times (spring and summer) are exhibited by populations that use high spring flows to access headwater or interior regions. Ocean-type populations within a basin that express different runs times appear to have evolved from a common source population. Stream-type populations appear to be nearly obligate yearling outmigrants (some 2-year-old smolts have been identified), they undertake extensive off-shore ocean migrations, and generally return to freshwater as spring- or summer-run fish. Stream-type populations are found in northern British Columbia and Alaska, and in the headwater regions of the Fraser River and Columbia River interior tributaries.

Prior to development of the ESU policy (Waples 1991), the NMFS recognized Sacramento River winter chinook salmon as a "distinct population segment" under the ESA (NMFS 1987). Subsequently, in reviewing the biological and ecological information concerning West Coast chinook salmon, Biological Review Teams (BRTs) have identified additional ESUs for chinook salmon from Washington, Oregon, and California: Snake River fall-run (Waples et al. 1991), Snake River spring- and summer-run (Matthews and Waples 1991), and Upper Columbia River summer- and fall-run chinook salmon (originally designated as the mid-Columbia River summer- and fall-run chinook salmon, Waknitz et al. 1995), Puget Sound chinook salmon, Washington Coast chinook salmon, Lower Columbia River chinook salmon, Upper Willamette River chinook salmon, Middle Columbia River spring-run chinook salmon, Upper Columbia River spring-run chinook salmon, Oregon Coast chinook salmon, Upper Klamath and Trinity rivers chinook salmon, Central Valley fall and late-fall-run chinook salmon, and Central Valley spring-run chinook salmon (Myers et al. 1998), the Southern Oregon and Northern California chinook salmon, California Coastal chinook salmon, and Deschutes River (NMFS 1999).

Of the 17 chinook salmon ESUs identified by the NMFS, eight are not listed under the United States ESA, seven are listed as threatened (Snake River spring- and summer-run chinook salmon, and Snake River fall-run chinook salmon [Federal Register, Vol. 57, No. 78, April 22, 1992, p. 14653]; Puget Sound chinook salmon, Lower Columbia River chinook salmon, and Upper Willamette River chinook salmon [Federal Register, Vol. 64, No. 56, March 24, 1999, p. 14308]; Central Valley fall-run, and California Coastal chinook salmon [Federal Register, Vol. 64, No. 179, September 16, 1999, p. 5039]), and two are listed as endangered (Sacramento River winter-run chinook salmon [Federal Register, Vol. 59, No. 2, January 4, 1994, p. 440], and Upper Columbia River spring-run chinook salmon [Federal Register, Vol. 64, No. 56, March 24, 1999, p. 14308]).

The NMFS convened a BRT to update the status of listed chinook salmon ESUs in Washington, Oregon, California, and Idaho. The chinook salmon BRT[1] met in January of 2003 in Seattle, WA to review updated information on each of the ESUs under consideration.

[1] The Biological Review Team (BRT) for the updated chinook salmon status review included, from the NMFS Northwest Fisheries Science Center: Thomas Cooney, Dr. Robert Iwamoto, Dr. Robert Kope, Gene Matthews, Dr. Paul McElhaney, Dr. James Myers, Dr. Mary Ruckelshaus, Dr. Thomas Wainwright, Dr. Robin Waples, and Dr. John Williams; from the NMFS Southwest Fisheries Science Center: Dr. Peter Adams, Dr. Eric Bjorkstedt, and Dr. Steve Lindley; from the NMFS Alaska Fisheries Science Center (Auke Bay Laboratory): Alex Wertheimer; and from the USGS Biological Resource Division: Dr. Reginald Reisenbichler.

# A.2.8. SACRAMENTO RIVER WINTER-RUN CHINOOK

## A.2.8.1. Previous BRT Conclusions

### Summary of major risk factors and status indicators

Historically, winter chinook were dependent on access to spring-fed tributaries to the upper Sacramento River that stayed cool during the summer and early fall. Adults enter freshwater in early winter and spawn in the spring and summer. Juveniles rear near the spawning location until at least the fall, when water temperatures in lower reaches are be suitable for migration. Winter chinook were abundant and comprised populations in the McCloud, Pit, and Little Sacramento, with perhaps smaller populations in Battle Creek and the Calaveras River. On the basis of commercial fishery landings in the 1870s, Fisher (1994) estimated that the total run size of winter chinook may have been 200,000 fish.

The most obvious challenge to winter chinook was the construction of Shasta Dam, which blocked access to the entire historic spawning habitat. It was not expected that winter chinook would survive this habitat alteration (Moffett 1949). Cold-water releases from Shasta, however, created conditions suitable for winter chinook for roughly 100 km downstream from the dam. Presumably, there were several independent populations of winter chinook in the Pitt, McCloud, Little Sacramento Rivers and various tributaries to these rivers such as Hat Creek and the Fall River, and these populations merged to form the present single population. If there ever were populations in Battle Creek and the Calaveras River, they have been extirpated.

In addition to having only a single extant population dependent on artificially-created conditions, winter chinook face numerous other threats. Chief among these is small population size: escapement fell below 200 fish in the 1980s. Population size declined monotonically from highs of near 100,000 fish in the late 1960s, indicating a sustained period of poor survival. There are questions of genetic integrity due to winter chinook having passed through several bottlenecks in the 20th century. Other threats include inadequately screened water diversions, predation at artificial structures and by nonnative species, overfishing, pollution from Iron Mountain mine (among other sources), adverse flow conditions, high summer water temperatures, unsustainable harvest rates, passage problems at various structures (especially, until recently, Red Bluff Diversion Dam), and vulnerability to drought.

### BRT conclusions

The chinook BRT spent little time considering the status of winter chinook, because winter chinook were already listed as endangered at the time of previous BRT meetings.

### Listing status

Winter chinook were listed as Threatened in 1990 and reclassified as Endangered 1994.

# A.2.8.2 Summary of New Information

## Viability assessments

Two studies have been done on the population viability of Sacramento River winter chinook. Botsford and Brittnacher, (1998), in a paper that is part of the draft recovery plan, developed de-listing criteria using a simple age-structured, density-independent model of spawning escapement. They concluded, on the basis of the 1967-1995 data, that winter chinook were certain to fall below the quasi-extinction threshold of 3 consecutive spawning runs with less than 50 females.

Lindley and Mohr, (in press) developed a slightly more complex Bayesian model of winter chinook spawning escapement that allowed for density dependence and a change in population growth rate in response to conservation measures initiated in 1989. This model, due to its allowance for the growth rate change, its accounting for parameter uncertainty, and use of newer data (through 1998), suggested a lower but still biologically significant expected quasi-extinction probability of 28%.

## Draft recovery plan

The draft recovery plan for winter chinook (NMFS 1997) provides a comprehensive review of the status, life history, habitat requirements, and risk factors of winter chinook. It also provides a recovery goal: an average of 10,000 females spawners per year and a $\lambda \geq 1.0$ calculated over 13 years of data (assuming a certain level of precision in spawning escapement estimates).

## New abundance data

The winter chinook spawning run has been counted at Red Bluff Diversion Dam (RBDD) fish ladders since 1967. Escapement has been estimated with a carcass survey since 1997. Through the mid-1980s, the RBDD counts were very reliable. At that time, changes to the dam operation were made to alleviate juvenile and adult passage problems. Now, only the tail end of the run (about 15% on average) is forced over the ladders, greatly reducing the accuracy of the RBDD counts. The carcass mark-recapture surveys were initiated to improve escapement estimates. The two measures are in very rough agreement, and there are substantial problems with both estimates, making it difficult to choose one as more reliable than the other. It does appear that the RBDD count is an underestimate, since the carcass survey crews have handled more carcasses than the RBDD estimate in some years, and only a fraction of the carcasses are available for capture. The problem with the carcass-based estimate is the estimation of this fraction—it appears that the probability of initial carcass recovery depends strongly on the sex of the fish and possibly on whether it has been previously recovered. In spite of these problems, both abundance measures suggest that the abundance of winter chinook is increasing. Based on the RBDD counts, the winter chinook population has been growing rapidly since the early 1990s (Figure A.2.8.1), with a short-term trend of 0.26 (Table A.2.8.1). On the population growth rate-population size space, the winter chinook population has a somewhat low population growth and moderate size compared to other Central Valley salmonid populations (Figure A.2.8.2).

Table A.2.8.1. Summary statistics for trend analyses. Numbers in parentheses are 0.90 confidence intervals

| Population | 5-yr mean | 5-yr min | 5-yr max | λ | μ | LT trend | ST trend |
|---|---|---|---|---|---|---|---|
| Sac. R. winter chinook | 2,191 | 364 | 65,683 | 0.97 (0.87, 1.09) | -0.10 (-0.21, 0.01) | -0.14 (-0.19, -0.09) | 0.26 (0.04, 0.48) |
| Butte Cr. spring chinook | 4,513 | 67 | 4,513 | 1.30 (1.09, 1.60) | 0.11 (-0.05, 0.28) | 0.11 (0.03, 0.19) | 0.36 (0.03, 0.70) |
| Deer Cr. spring chinook | 1,076 | 243 | 1,076 | 1.17 (1.04, 1.35) | 0.12 (-0.02, 0.25) | 0.11 (0.02, 0.21) | 0.16 (-0.01, 0.33) |
| Mill Cr. spring chinook | 491 | 203 | 491 | 1.19 (1.00, 1.47) | 0.09 (-0.07, 0.26) | 0.06 (-0.04, 0.16) | 0.13 (-0.07, 0.34) |
| Sac. R. steelhead | 1,952 | 1,425 | 12,320 | 0.95 (0.90, 1.02) | -0.07 (-0.13, 0.00) | -0.09 (-0.13, -0.06) | -0.06 (-0.26, 0.15) |

Winter chinook may be responding to a number of factors, including wetter-than-normal winters, reduced harvest, changes in RBDD operation, installation of a cold-water release device on Shasta Dam, changes in operations of the state and federal water projects, and a variety of other habitat improvements. While the status of winter chinook is improving, there is only one winter chinook population and it is dependent on cold-water releases of Shasta Dam, which could be vulnerable to a prolonged drought. The recent 5-year geometric mean is only 3% of the maximum post-1967 5-year geometric mean.

The RBDD counts are suitable for modeling as a random-walk-with-drift (also known as the "Dennis model" [Dennis et al., 1991]). In the RWWD model, population growth is described by exponential growth or decline:

$$N_{t+1} = N_t \exp(\mu + \eta_t), \tag{1}$$

where $N_t$ is the population size at time $t$, $\mu$ is the mean population growth rate, and $\eta_t$ is a normal random variable with mean=0 and variance = $\sigma^2_p$.

Table A.2.8.2. Parameter estimates for the constant-growth and step-change models applied to winter chinook. Numbers in parentheses indicate 90% confidence intervals.

| | model | |
|---|---|---|
| parameter | constant □ | step change □ |
| $\mu$ | ˜0.085 | ˜0.214 |
| | ˜0.181,0.016 | ˜(0.322˜,0.113) |
| $\delta$ | NA | 0.389 |
| | NA | (0.210, 0.574) |
| $\sigma^2_p$ | 0.105 | 0.056 |
| | (0.0945, 0.122) | (0.046, 0.091) |
| $\sigma^2_m$ | 0.0025 | 0.011 |
| | ($2.45\times10^6$, 0.0126) | ($3.92\times10^6$, 0.022) |
| $P_{100}$(ext)[a] | 0.40 | 0.003 |
| | (0.00, 0.99) | (0.0, 0.0) |

[a] Probability of extinction (pop. size < 1 fish) within 100 years.

The RWWD model, as written in Equation 1, ignores measurement error. Observations ($y_t$) can be modeled separately,

$$y_t = N_t \exp(\varepsilon_t), \tag{2}$$

where $\varepsilon_t$ is a normal random variable with mean = 0 and variance = $\sigma^2_m$. Equations 1 and 2 together define a state-space model that, after linearizing by taking logarithms, can be estimated using the Kalman filter (Lindley, in press).

A recent analysis of the RBDD data (Lindley and Mohr, in press) indicated that the population growth since 1989 was higher than in the preceding period. For this reason, I fit two forms of the RWWD model- one with a fixed growth rate (constant-growth model) and another with a growth rate with a step-change in 1989, when conservation actions began (step-change model, $\mu_t = \mu$ for $t < 1989$, $\mu_t = \mu + \delta$ for $t \geq 1989$). In both cases, a 4-year running sum was applied to the spawning escapement data to form a total population estimate (Holmes, 2001). Results of model fitting are shown in Table A.2.8.2. The constant-growth model satisfies all model diagnostics, although visual inspection of the residuals shows a strong tendency to under-predict abundance in the most recent 10 years. The residuals of the step-change model fail the Shapiro-Wilks test for normality; the residuals look truncated on the positive side, meaning that good years are not as extreme as bad years. Winter chinook growth rate might be better modeled as a mixture between a normal distribution and another distribution reflecting near-catastrophic population declines caused by episodic droughts.

According to Akaike's information criterion (AIC), the step-change model is a much better approximation to the data than the constant population growth rate model, with an AIC difference of 9.61 between the two models (indicating that the data provide almost no support for the constant-growth model). The step-change model suggests the winter chinook population currently has a $\lambda$ of 1.21, while for the constant population growth rate model, $\lambda = 0.97$[4]. The extinction risks predicted by the two models are extremely different: winter chinook have almost no risk of extinction if the apparent recent increase in $\lambda$ holds in the future, but are certain to go extinct if the population grows at its average rate, with a most likely time of extinction being 100 years. While it would be dangerous to assume that recent population growth will hold indefinitely, it does appear that the status of winter chinook is improving.

## Harvest impacts

Substantial changes in ocean fisheries off central and northern California have occurred since the last status review (PFMC 2002a, b). Ocean harvest rate of winter chinook is thought to be a function of the Central Valley chinook ocean harvest index (CVI), which is defined as the ratio of ocean catch south of Point Arena to the sum of this catch and the escapement of chinook to Central Valley streams and hatcheries. Note that other stocks (e.g., Klamath chinook) contribute to the catch south of Point Arena. This harvest index ranged from 0.55 to nearly 0.80 from 1970 to 1995, when harvest regimes were adjusted to protect winter chinook. In 2001, the CVI fell to 0.27. The reduction in harvest is presumably at least partly responsible for the record spawning escapement of fall chinook ($\approx$ 540,000 fish in 2001).

Because they mature before the onset of the ocean fishing season, winter chinook should have lower harvest rates than fall chinook. At the time of the last status review, the only information of the harvest rate of winter chinook came from a study conducted in the 1970s. The impact rate (direct and indirect effects of harvest) of ocean fisheries on winter chinook was estimated to be 0.54, and the river sport fishery at that time was thought to have an impact rate of 0.08.

The recent release of significant numbers of ad-clipped winter chinook provides new, but limited, information on the harvest of winter chinook in coastal recreational and troll fisheries. The 1998 brood year was the first brood to have sufficient tag releases. Dan Viele (Sustainable Fisheries, SWR) conducted a cohort reconstruction of the 1998 broodyear. Winter chinook are mainly vulnerable to ocean fisheries as 3-year olds. Viele calculated, on the basis of 123 coded-wire-tag recoveries, that the ocean fishery impact rate on 3-year-olds is 0.21 and the in-river sport fishery impact rate is 0.24. For a given year, these fisheries combine to reduce spawning escapement by about 43%. The high estimated rate of harvest in the river sport fishery, which arises from the recovery of 8 coded-wire tags, was a surprise, because salmon fishing is closed from January 15 to July 31 to protect winter-run chinook. The tags were recovered in late December/early January, at the tail end of the fishery for late-fall chinook. The estimate of river sport fishery impact is much less certain than the ocean fishery impact estimate because of the lower number of tag recoveries, less rigorous tag sampling, and larger expansion factors. Never the less, in response to this information, the California Fish and Game Commission is moving

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[4] In this section of the document $\lambda$ is defined as $\exp(\mu + \sigma^2_p / 2)$, the *mean* annual population growth rate.

forward with an emergency action to amend sport fishing regulations to ban retention of salmon caught in river sport fisheries on January 1 rather than January 15. Had such regulations been in place in 1999/2000, the harvest rate would have been 20% of that observed.

**New hatchery information**

Livingston Stone National Fish Hatchery (LSNFH) was constructed at the base of Shasta Dam in 1997, with the sole purpose of helping to restore natural production of winter chinook. LSNFH was designed as a conservation hatchery with features intended to overcome the problems of CNFH (better summer water quality, natal water source). All production is ad-clipped. Each individual considered for use as broodstock is genotyped to ensure that it is a winter chinook. No more than 10% of the broodstock is composed of hatchery origin fish, and no more than 15% of the run is taken for broodstock, with a maximum of 120 fish. Figure 3 shows the number of winter chinook released by CNFH/LSNFH; Figure 4 shows the returns to these hatcheries.

## A.2.8.3 New Comments

The California State Water Contractors, the San Luis and Delta-Mendota Water Authority, and the Westlands Water District recommend that the listing status of winter chinook be changed from endangered to threatened. They base this proposal on the recent upturn of adult abundance, recently initiated conservation actions (restoration of Battle Creek, ocean harvest reductions, screening of water diversions, remediation of Iron Mountain Mine, and improved temperature control), and a putative shift in ocean climate in 1999.

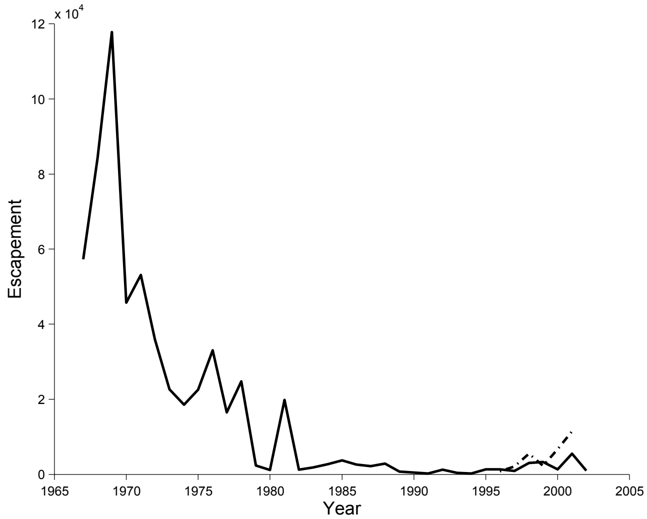


Figure A.2.8.1. Estimated winter chinook spawner abundance as determined by RBDD fish ladder (solid line) and carcass mark-recapture (dashed line).

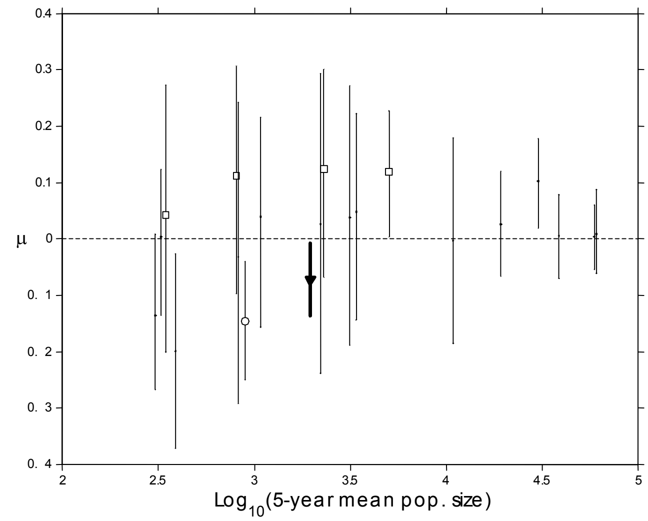


Figure A.2.8.2. Abundance and growth rate of Central Valley salmonid populations. Open circle- steelhead; open squares- spring chinook; filled triangle- winter chinook; small black dots- other chinook stocks. Error bars represent central 0.90 probability intervals for μ estimates. (Note: as defined in other sections of the status reviews, μ ≈ log(λ).)

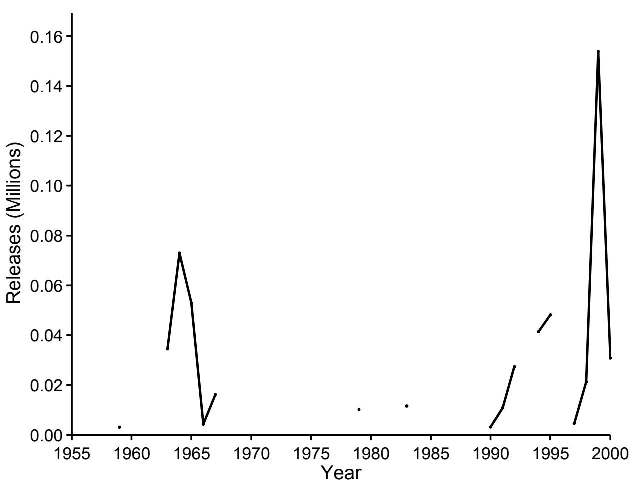


Figure A.2.8.3. Number of juvenile winter-run chinook released by Coleman and Livingston Stone National Fish Hatcheries.

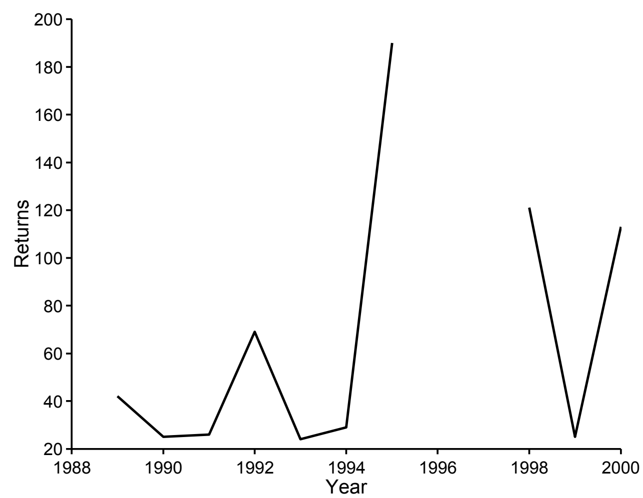


Figure A.2.8.4. Number of adult winter-run chinook captured by Coleman and Livingston Stone National Fish Hatcheries.